

CLAIMS

1. A hydraulic valve actuator for reciprocating engines, characterized in that it comprises:

- 5 ❖ at least one hydraulic jack (3) connected to a high-pressure hydraulic circuit (10) by means of a duct and ensuring the opening of at least one valve (2),
- 10 ❖ at least one hydraulic positive displacement pump (4) comprising at least one outlet and at least one inlet, and rotating at a speed proportional to that of the engine crankshaft,
- 15 ❖ at least one pump outlet plug (8) which makes it possible to prevent the hydraulic fluid expelled at the outlet of the hydraulic positive displacement pump (4) from issuing into a low-pressure circuit (9) or into a reservoir (58) and to force it into a high-pressure circuit (10) communicating with one or more hydraulic jacks (3) ensuring the opening of one or more valves (2),
- 20 ❖ at least one valve opening selector (11) which makes it possible to direct, via the high-pressure circuit (10), the hydraulic fluid expelled at the outlet of the hydraulic positive displacement pump (4) toward the hydraulic jack (3) of at least one valve (2) to be opened, while at the same time preventing said hydraulic fluid from being directed toward one or more other valves (2) to remain closed,
- 25 ❖ at least one opening nonreturn valve (24) which is located on the high-pressure circuit (10) between the outlet or outlets of the hydraulic positive displacement pump (4) and the hydraulic jack (3) of at least one valve (2) and which makes it possible to retain the hydraulic fluid in said hydraulic jack (3) of said valve (2) in order to keep it open,
- 30 ❖ at least one valve closing selector (25) which makes it possible to direct the hydraulic fluid contained in the hydraulic jack (3) of at least one valve (2) kept open
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by the opening nonreturn valve (24) toward the inlet or inlets of the hydraulic positive displacement pump (4), in order to ensure the closing of said valve or valves (2) and to prevent the hydraulic fluid contained in their hydraulic jack (3) from being introduced into the hydraulic jack (3) of another valve or other valves (2) which is or are to remain in a closed position,

❖ and at least one pump inlet nonreturn valve (26) which is located at the inlet or inlets of the hydraulic positive displacement pump (4) and which makes it possible for the hydraulic fluid of the low-pressure circuit (9) or of the reservoir (58) to be admitted at the inlet or inlets of the hydraulic positive displacement pump (4) when the pressure of said low-pressure circuit (9) or of said reservoir (58) is higher than that of said inlet or inlets of the hydraulic positive displacement pump (4).

2. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the cylinder and the chamber (20) of the hydraulic jack (3) ensuring the opening of the valve or valves (2) are arranged in a valve guide (16), said cylinder and said chamber (20) cooperating with a jack piston consisting of a shoulder (19) arranged on the valve stem (18) in order to open the valve (2).

3. The hydraulic valve actuator for reciprocating engines as claimed in claim 2, **characterized in that** the jack piston consisting of a shoulder (19) arranged on the valve stem (18) participates in guiding the valve (2) in the valve guide (16).

4. The hydraulic valve actuator for reciprocating engines as claimed in claim 2, **characterized in that** the jack piston consisting of a shoulder (19) on the valve stem (18) comprises at least one seal (17).

5. The hydraulic valve actuator for reciprocating engines as claimed in claim 2, **characterized in that** the valve guide (16) comprises at least one drain (22) in the vicinity of the intake or exhaust duct (21), which the cylinder head of the engine (12) comprises in order to limit the passage of the hydraulic fluid toward said intake or exhaust duct (21).

6. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the hydraulic jack (3) ensuring the opening of the valve or valves (2) comprises a limit-stop damping device making it possible to brake the valve or valves (2) before said valves come into contact with their seat.

7. The hydraulic valve actuator for reciprocating engines as claimed in claim 6, **characterized in that** the hydraulic jack (3) arranged in the valve guide (16) comprises a limit-stop damping device consisting of a small shoulder (23) which is arranged on the valve stem (18) and which cooperates with cylinder portion of small height and of a diameter substantially larger than said small shoulder (23), said cylinder portion being arranged in the upper part of the valve guide (16) in order to shear the hydraulic fluid when the valve (2) reaches the end of the closing stroke, the effect of which is to reduce the speed of said valve (2).

8. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the hydraulic jack (3) ensuring the opening of at least one valve (2) comprises, in the region of its chamber (20), a bleeding device consisting of a plug which can be opened by means of a command in order to make it possible for the hydraulic fluid contained in said chamber (20) to escape toward a low-pressure circuit.

9. The hydraulic valve actuator for reciprocating engines

as claimed in claim 1, **characterized in that** at least one valve (2) is equipped with a measuring device emitting an electrical or electromagnetic signal which informs a computer of the lift height of the valve at a given moment.

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10. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the low-pressure circuit (9) is connected to the pressurized lubrication circuit (15) of the engine (12).

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11. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the low-pressure circuit (9) is independent of the pressurized lubrication circuit (15) of the engine (12).

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12. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the low-pressure circuit (9) is independent of the pressurized lubrication circuit (15) of the engine (12) and is kept at a pressure higher than the atmospheric pressure by means of an additional pump (13).

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13. The hydraulic valve actuator for reciprocating engines as claimed in claim 12, **characterized in that** the low-pressure circuit (9) comprises a pressure accumulator (14).

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14. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the hydraulic positive displacement pump (4) is a vane pump, the stator of which has an inner profile which defines at least one inlet and one outlet which are independent.

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15. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the hydraulic positive displacement pump (4) is a gear pump comprising at least two pinions and at least one inlet and one outlet which are independent.

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16. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the hydraulic positive displacement pump (4) is a variable displacement pump which makes it possible to vary the lifting speed of the valve or valves (2) of the engine (12) under given operating conditions of said engine.

17. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the pump outlet plug (8) is a solenoid valve controlled by a computer.

18. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the pump outlet plug (8) is a rotary mechanical device contained in a plug housing (65) and rotating at a speed proportional to that of the crankshaft (5) of the engine (12), and comprising a plug rotor (27) equipped with at least one protuberance (28) periodically plugging one or more pump outlet ports (29) accommodated in said plug housing (65) during the rotation of said plug rotor (27).

19. The hydraulic valve actuator for reciprocating engines as claimed in claim 18, **characterized in that** the leaktightness between the pump outlet port or ports (29) and the protuberances (28) of the plug rotor (27) is reinforced by a device (30) for keeping said pump outlet port or ports (29) in contact with said protuberances (28) when the latter are positioned opposite said pump outlet port or ports (29).

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20. The hydraulic valve actuator for reciprocating engines as claimed in either one of claims 18 and 19, **characterized in that** the device (30) for keeping in contact consists of a plug piston (31) which is positioned radially in the plug housing (65) and which comprises a pump outlet port (29) which passes right through it longitudinally, said pump outlet port (29) being connected to a pump outlet duct (32)

by means of a radial port (33), said plug piston (31) comprises a concave cylindrical bearing face having a radius substantially identical to that of the protuberances (28), so as to have a wide contact surface with said protuberances (28), the plug piston (31) has, on the side of the plug housing (65), a surface subjected to the pressure of the hydraulic fluid which is greater than the contact surface which it has with the protuberances (28), so that said plug piston is kept in contact with said protuberances when the pressure of the fluid increases in the pump outlet duct (32) during the passage of said protuberances (28), and, when there is no protuberance plugging the pump outlet port (29) of the plug piston (31), the latter is kept in bearing contact on the plug housing (65) by means of a spring (56).

21. The hydraulic valve actuator for reciprocating engines as claimed in claim 20, **characterized in that** the plug piston (31) comprises at least one seal ensuring leaktightness between said plug piston (31) and the bore in which it is accommodated.

22. The hydraulic valve actuator for reciprocating engines as claimed in claim 18, **characterized in that** the plug rotor (27) is equipped with a device for angular phase shift with respect to the crankshaft (5) of the engine (12), so that the opening of the valve or valves (2) can be advanced or retarded.

23. The hydraulic valve actuator for reciprocating engines as claimed in claim 22, **characterized in that** the angular phase-shifting device of the plug rotor (27) consists of at least one helical spline arranged on the inside of said plug rotor (27) and cooperating with at least one helical spline arranged on the outside of the driveshaft of said plug rotor (27), the phase shift taking place by means of the translation of said plug rotor (27) parallel to its axis of rotation by means of a fork, and the protuberances being of

sufficient width to plug the pump outlet port or ports (29) accommodated in said plug housing (65), whatever their position with respect to the latter.

5 24. The hydraulic valve actuator for reciprocating engines as claimed in claim 18, **characterized in that** the protuberances (28) of the plug rotor (27) are wide and of variable cross section over the length of the plug rotor (27), so that they have a plugging time which varies as a
10 function of the longitudinal position of the plug rotor (27) with respect to the pump outlet port or ports (29), thus making it possible to increase or reduce the lift stroke of the valve or valves (2), and the longitudinal position of the plug rotor (27) with respect to said pump outlet port or
15 ports (29) is controlled by means of a valve lift fork (62) which makes it possible to impart to said plug rotor (27) a translation parallel to its axis of rotation, said plug rotor (27) comprising at least one straight inner spline cooperating with at least one straight outer spline which a
20 driveshaft comprises.

25 25. The hydraulic valve actuator for reciprocating engines as claimed in any one of claims 18, 23 and 24, **characterized in that** the angular phase-shifting device of the plug rotor (27), which makes it possible to advance or retard the opening of the valve or valves (2), consists of an opening sleeve (37) comprising, on the one hand, at least one inner helical spline (75) cooperating with at least one outer helical spline (60) which the driveshaft of said opening
30 sleeve (37) comprises and, on the other hand, at least one straight outer spline (76) cooperating with at least one straight inner spline (34) which the plug rotor (27) comprises, said opening sleeve (37) being capable of being actuated in terms of translation parallel to its axis of
35 rotation by means of a valve opening advance fork (61), in order to advance or retard the opening of the valve or valves (2) by means of the angular phase shift of the plug

rotor (27) which it drives in rotation, while the lift of the valve or valves (2) is controlled independently by means of the valve lift fork (62) which acts on the longitudinal position of the plug rotor (27) with respect to the pump outlet port or ports (29), said plug rotor (27) comprising the protuberances (28) of variable cross section which ensure a variable plugging time.

26. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the valve opening selector (11) consists of one or more solenoid valves controlled by a computer.

27. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the valve opening selector (11) is a rotary mechanical device contained in a housing and rotating at a speed proportional to that of the crankshaft (5) of the engine (12).

28. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the valve opening selector (11) is a rotary mechanical device contained in a selector housing (66), rotating at a speed proportional to that of the crankshaft (5) of the engine (12) and comprising an opening selector rotor (38) equipped with a cam (39) which actuates one or more valve opening distributors arranged radially in the selector housing (66).

29. The hydraulic valve actuator for reciprocating engines as claimed in either one of claims 1 and 27, **characterized in that** the opening selector rotor (38) is equipped with a device for angular phase shift with respect to the crankshaft (5) of the engine (12), so that the valve opening selector (11) can be synchronized with the pump outlet plug (8) and can select the valve or valves (2) at the desired moment.

30. The hydraulic valve actuator for reciprocating engines as claimed in any one of claims 1, 25 and 28, **characterized in that** the opening selector rotor (38) comprising a cam (39) is integral with the opening sleeve (37), thus making
5 it possible for the valve opening selector (11) to remain synchronized with the opening moment of the valve or valves (2) which depends on the angular phase shift of the plug rotor (27) with respect to the crankshaft (5) of the engine (12), the valve opening advance fork (61) then making it
10 possible, simultaneously and in the same proportions, to shift the phase of the opening selector rotor (38) and the plug rotor (27) with respect to the crankshaft (5).

31. The hydraulic valve actuator for reciprocating engines as claimed in either one of claims 28 and 29, **characterized in that** the angular phase-shifting device of the opening selector rotor (38) consists of at least one helical spline (77) arranged on the inside of said opening selector rotor (38) and cooperating with at least one helical spline
20 arranged on the outside of the driveshaft of said opening selector rotor (38), the phase shift taking place by means of a fork as a result of the translation of said opening selector rotor (38) parallel to its axis of rotation, and the cam (39) being of sufficient width to actuate the valve
25 opening distributors, whatever its longitudinal position with respect to the latter.

32. The hydraulic valve actuator for reciprocating engines as claimed in claim 28, **characterized in that** each valve
30 opening distributor (40) consists of a cylindrical piece (78) equipped with at least one groove (41) and accommodated in a bore arranged in the selector housing (66), each groove (41) being brought, by means of the axial translation of the cylindrical piece (78) imparted by the cam (39), level with
35 at least one duct (42) arranged in the selector housing (66), in order to make it possible for the hydraulic fluid to circulate in each duct (42), said cylindrical piece (78)

being kept at a desired distance from the opening selector rotor (38) by the twin action of a shoulder (44) arranged on said cylindrical piece (78) and bearing on the selector housing (66) and of a spring (43) kept compressed by a cap (45) screwed into the selector housing (66).

33. The hydraulic valve actuator for reciprocating engines as claimed in claim 32, **characterized in that** the cap (45) screwed in the selector housing (66) defines a chamber (46) which contains the spring (43) and which is connected to the low-pressure circuit (9) or to the reservoir (58) by means of a duct.

34. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the valve closing selector (25) consists of one or more solenoid valves controlled by a computer.

35. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the valve closing selector (25) is a rotary mechanical device contained in a housing and rotating at a speed proportional to that of the crankshaft (5) of the engine (12).

36. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the valve closing selector (25) is a rotary mechanical device contained in a housing and rotating at a speed proportional to that of the crankshaft (5) of the engine (12) and comprising a closing selector rotor (47) equipped with a cam (48) which actuates one or more valve closing distributors arranged radially in said housing.

37. The hydraulic valve actuator for reciprocating engines as claimed in either one of claims 1 and 34, **characterized in that** the closing selector rotor (47) is equipped with a device for angular phase shift with respect to the

crankshaft (5) of the engine (12), so that the closing of the valve or valves (2) can be advanced or retarded.

38. The hydraulic valve actuator for reciprocating engines
5 as claimed in either one of claims 36 and 37, **characterized in that** the phase-shifting device of the closing selector rotor (47) consists of at least one helical spline (79) arranged on the inside of said closing selector rotor (47) and cooperating with at least one helical spline arranged on
10 the outside of the driveshaft of said closing selector rotor (47), the phase shift taking place by means of a valve closing retard fork (63) by means of the translation of said closing selector rotor (47) parallel to its axis of rotation, and the cam (48) being of sufficient width to
15 actuate the valve closing distributors (49), whatever its longitudinal position with respect to the latter.

39. The hydraulic valve actuator for reciprocating engines as claimed in claim 36, **characterized in that** each valve
20 closing distributor (49) consists of a cylindrical piece (80) equipped with at least one groove (50) and accommodated in a bore arranged in the selector housing (66), each groove (50) being brought, by means of the axial translation of the cylindrical piece (80) imparted by the cam (48), level with
25 at least one duct (42) arranged in the selector housing (66), in order to make it possible for the hydraulic fluid to circulate in each duct (42), said cylindrical piece (80) being kept at a desired distance from the closing selector rotor (47) by the twin action of a shoulder (51) arranged on
30 said cylindrical piece (80) and bearing on the selector housing (66) and of a spring (52) kept compressed by a cap (53) screwed into the selector housing (66).

40. The hydraulic valve actuator for reciprocating engines
35 as claimed in claim 39, **characterized in that** the cap (53) screwed in the selector housing (66) defines a chamber (73) which contains the spring (52) and which is connected to the

low-pressure circuit (9) or to the reservoir (58) by means of a duct.

41. The hydraulic valve actuator for reciprocating engines
5 as claimed in claim 1, **characterized in that** the high-
pressure circuit (10) comprises at least one closing
nonreturn valve (54) upstream or downstream of the valve
closing selector (25), in order to prevent the hydraulic
10 fluid contained in the hydraulic jack (3) of one or more
valves (2) in the closing phase from being capable of being
introduced into the hydraulic jack (3) of another valve or
other valves (2) which are to remain closed.

42. The hydraulic valve actuator for reciprocating engines
15 as claimed in claim 41, **characterized in that** the closing
nonreturn valve (54) positioned upstream or downstream of
the valve closing selector (25) consists of a ball kept on
its seat by means of a spring.

20 43. The hydraulic valve actuator for reciprocating engines
as claimed in claim 1, **characterized in that** the pump inlet
nonreturn valve (26) consists of a ball kept on its seat by
means of a spring.

25 44. The hydraulic valve actuator for reciprocating engines
as claimed in either one of claims 1 and 41, **characterized**
in that the hydraulic positive displacement pump (4), the
pump outlet plug (8), the valve opening selector (11), the
opening nonreturn valve or valves (24), the valve closing
30 selector (25) and the closing nonreturn valve or valves
(54), as components, are contained together or in groups in
a common housing consisting of one or more parts.

45. The hydraulic valve actuator for reciprocating engines
35 as claimed in any one of claims 1, 18, 28 and 36,
characterized in that the hydraulic positive displacement
pump (4), the plug rotor (27), the selector rotor (38) and

the closing selector rotor (47) or any combination of these four devices are driven in rotation by means of a common shaft (59), itself driven in rotation by the crankshaft (5) of the engine (12) by means of a transmission device.

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46. The hydraulic valve actuator for reciprocating engines as claimed in claim 45, **characterized in that** the transmission device driving the common shaft (59) consists of a pulley (74) driven in rotation by the crankshaft (5) of the engine (12) by means of a notched belt or a chain or a gear system consisting of at least one pinion.

47. The hydraulic valve actuator for reciprocating engines as claimed in any one of claims 23, 25, 31, 38 and 45, **characterized in that** the common shaft (59) is equipped with at least one helical spline (60) which drives in rotation the plug rotor (27), the opening selector rotor (38), the opening sleeve (37) and the closing selector rotor (47) or any combination of these three devices and cooperates with the helical splines of some of its devices in order to allow their angular phase shift with respect to the crankshaft (5) of the engine (12).

48. The hydraulic valve actuator for reciprocating engines as claimed in any one of claims 1, 18, 23, 24, 28, 36, 38, 41 and 45, **characterized in that** the common housing consists of four main housings which contain the common shaft (59) and which are assembled end to end, with respectively:

- 30 ❖ a pump housing (64) comprising the hydraulic positive displacement pump (4) and the pump inlet nonreturn valve or valves (26),
- ❖ a plug housing (65) containing the plug rotor (27) and the pump outlet port or ports (29),
- 35 ❖ a selector housing (66) containing the valve lift fork (62), the opening selector rotor (38), the valve opening distributor or distributors (40), the valve

opening advance fork (61), the closing selector rotor (47), the valve closing distributor or distributors (49), the valve closing retard fork (63) and the opening nonreturn valve or valves (24) and capable of comprising the closing nonreturn valve or valves (54),
❖ and a closing collector housing (67).

49. The hydraulic valve actuator for reciprocating engines as claimed in either one of claims 1 and 48, **characterized in that** the plug housing (65) has passing through it ducts connecting the outlet or outlets (6) of the hydraulic positive displacement pump (4) to the pump outlet plug or plugs (8), on the one hand, and to an opening collector (68) consisting of a network of ducts which is arranged at the parting plane between the plug housing (65) and the selector housing (66), on the other hand, and connecting the inlet or inlets (7) of the hydraulic positive displacement pump (4) to a closing collector (69) consisting of a network of ducts which is arranged at the parting plane between the selector housing (66) and the closing collector housing (67).

50. The hydraulic valve actuator for reciprocating engines as claimed in any one of claims 1, 48 and 49, **characterized in that** the selector housing (66) has passing through it longitudinally ducts (42) which connect the opening collector (68) and the closing collector (69) and which can be shut off or opened by means of the valve opening distributor or distributors (40) and by means of the valve closing distributor or distributors (49), said ducts (42) comprising valve outgoing ducts (70) which are located between the valve opening distributor or distributors (40) and the valve closing distributor or distributors (49) and which are connected to the hydraulic jack (3) of the valve or valves (2), said selector housing (66) likewise having passing through it longitudinally one or more ducts which connect the closing connector (69) to the inlet or inlets (7) of the hydraulic positive displacement pump (4).

51. The hydraulic valve actuator for reciprocating engines as claimed in any one of claims 1 and 48, 49 and 50, **characterized in that** the opening collector (68) makes it possible to connect to one another the ducts (42) which pass longitudinally through the selector housing (66) and which are to be connected to the same pump outlet (6), said pump outlet (6) being connected to said opening collector (68) by means of the duct which passes through the plug housing (65), while the closing collector (69) makes it possible to connect to one another the ducts (42) which pass longitudinally through the selector housing (66) and which are to be connected to the same pump inlet (7), said pump inlet (7) being connected to said closing collector (69) by means of the ducts (42) which pass respectively through the selector housing (66) and the plug housing (65).

52. The hydraulic valve actuator for reciprocating engines as claimed in either one of claims 1 and 48, **characterized in that** assembly screws (71) pass right through the various housings (64, 65, 66 and 67) in order to keep them assembled, one or more of said assembly screws (71) being capable of serving as slideway for the forks (61, 62 and 63) which make it possible to control the opening, lift and closing of the valves (2).

53. The hydraulic valve actuator for reciprocating engines as claimed in any one of claims 1, 23, 24 and 38, **characterized in that** the valve opening advance fork (61), the valve lift fork (62) and the valve closing retard fork (63) are actuated in terms of translation by means of electric motors controlled by a computer and connected to said forks (61, 62 and 63) by transmission means.

54. The hydraulic valve actuator for reciprocating engines as claimed in any one of claims 1, 10, 11, 12, 18 and 44, **characterized in that** the pump outlet port or ports (29)

which the protuberances (28) of the plug rotor (27) shut off issue on the inside of the common housing which comprises, in particular, the common shaft (59), said common housing forming a closed chamber connected:

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- ❖ to the engine lubricating oil housing (72) by means of a duct,
- ❖ or to the pressurized lubrication circuit (15) of the engine (12),
- 10 ❖ or to a hydraulic fluid housing independent of the engine lubricating oil housing (72),
- ❖ or kept under pressure by the additional pump (13).

55. The hydraulic valve actuator for reciprocating engines
15 as claimed in claim 1, **characterized in that** the same duct connected to the high-pressure hydraulic circuit (10) simultaneously feeds a plurality of hydraulic jacks (3) via a flow divider which ensures that the valves (2) actuated by said hydraulic jacks (3) have a substantially identical
20 lift.

56. The hydraulic valve actuator for reciprocating engines as claimed in claim 1, **characterized in that** the pump outlet plug (8) and the valve opening selector (11) are gathered
25 together in a single combined distributor (81) comprising at least one inlet connected to the outlet (6) of the hydraulic positive displacement pump (4) and capable of being put in relation either with an outlet connected to the low-pressure circuit (9) or with an outlet connected to at least one
30 hydraulic jack (3).

57. The hydraulic valve actuator for reciprocating engines as claimed in either one of claims 1 and 44, **characterized in that** the common housing comprises a plinth in which at
35 least one hydraulic jack (3) is accommodated, said plinth being fastened to the cylinder head of the engine (12), so that each hydraulic jack (3) is in contact with the upper

end of the stem of the corresponding valve (2) of said engine (12) and can actuate said valve.